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A METHOD TO CONVERT TWO DIMENSIONAL MOTION PICTURES
FOR THREE-DIMENSIONAL SYSTEMS

TECHNICAL FIELD

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The invention relates to a method for converting existing film or videotape motion pictures to a form that can be used with three-dimensional systems for broadcast or exhibition.

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BACKGROUND ART

With the advent of stereophonic sound, various techniques were developed to convert or 're-process' existing monophonic programs for stereophonic broadcast or recording systems. These included modifying the ¹equalization, phase or tonal qualities of ²separate copies of the monophonic program for the left and right channels.

While true stereophonic or binaural effects may not have been

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1 achieved, the effects were much improved over feeding the identical monophonic signal to both channels.

5 Similarly, with the almost universal use of color production, exhibition and broadcast systems for motion ~~pictures~~^{pictures} and television, systems have been developed to convert existing monochrome or black & white materials to color programs. Such a system³ is described in applicant Geshwind's patent number ³4,606,625, issued August 19, 1986. The results of these colorized
10 products, while not always identical to true color motion pictures, are more suitable than black & white for color systems.

There have been a number of systems for exhibition or display of left- and right-eye pairs of binocular motion pictures. Early
15 systems required two completely redundant projection or display systems; e.g. two film projectors or CRT television displays, each routed to one eye via mirrors. Other systems require either complicated and expensive projection or display ~~systems~~^{systems}, or expensive 'glasses' to deliver two separate images. For example:

¹ P1 red- and green-tinted monochrome images are both projected or displayed to be viewed through glasses with left and right lenses tinted either red or green;

25 ² P1 two full-color images are projected through mutually perpendicular ~~polarized~~^{polarized} filters and viewed through glasses with lenses that are also polarized in the same manner;

30 ³ P1 left and right images are displayed on alternate odd and even fields (or frames) of a standard (or high scan rate) television CRT and are viewed through 'glasses'² with shutters (either rotating blades or flickering LCDs, for example) that alternate the view of left and right eyes in synchrony with the odd or even fields of the CRT.

- 19 Of the above systems, the second is not at all usable with standard home television receivers, the third requires very expensive 'glasses' and may flicker with standard home receivers, and the first produces only ³ ~~strangely~~ ^{compatible} tinted monochrome images.
- 5 Further, none of the systems may be broadcast over standard television for unimpeded viewing without special glasses.

Thus, until now, ~~compatible~~ ^{compatible} (i.e., viewable as two-dimensional, without glasses) home reception of 3-D images was not possible.

- 10 However, a new system, which takes advantage of differential processing of left- and right-eye images in the human perceptual system, delivers a composite image on a standard home television ~~receiver~~ ^{receiver} that can be viewed as a normal 2-D picture without glasses. Very inexpensive glasses, with one light and one dark
- 15 lens, accentuate the differential processing of the image, as viewed by each eye, to produce a 3-D depth effect.

- Practical, inexpensive, ~~compatible~~ ^{compatible} (with standard TV) 3-D television may now become widespread. In addition to materials specifically produced for the new system (or other 3-D systems) conversion of standard 2-D programs to 3-D format would provide additional product to broadcast using the new ~~compatible~~ ^{compatible} system (or for other 3-D projection systems).

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SUMMARY OF THE INVENTION

- Applicant Handal's previous application, number 479,679, filed March 28, 1983 and now abandoned, relates a process and apparatus for deriving left- and right-eye pairs of binocular images, from certain types of two dimensional film materials. In particular, the materials must consist of ~~separate~~ ^{separate} foreground and background elements, such as cartoon animation cells and background art. By taking into account the parallax between scenes as viewed by the

1 left and right eyes, two images are prepared where foreground
elements are shifted with respect to background elements by an
amount that indicates their depth in the third dimension. Two-
dimensional motion pictures that consist of a series of single
5 composite images could not be converted to three-dimensional
format, by this technique, without first being ~~separated~~ ^{separated} into
various background and foreground elements.

a Once committed to two-dimensional motion pictures, the ~~separation~~ ^{separation}
10 and depth information for various scene elements, in the third
dimension, are lost. Thus, the ~~separation~~ ^{separation} of two-dimensional
image sequences into individual image elements and the generation
of three-dimensional depth information for each such image
element are not simple or trivial tasks, and are the further
15 subject of the instant invention.

In accordance with the invention, standard two-dimensional motion
picture film or videotape may be converted or processed, for use
with three-dimensional exhibition or transmission systems, so as
20 to exhibit at least some three-dimensional or depth character-
istics. ~~Separation~~ ^{Separation} of a single 2-D image stream into diverse
elements is accomplished by a computer assisted, human operated
system. (If working from discrete 2-D film ~~sub-components~~ ^{sub-components}, such
as animation elements, the ~~separation~~ ^{separation} step may be ~~omitted~~ ^{omitted}.)
a25 information is assigned to various elements by a combination of
human decisions and/or computer analyses and resulting images of
three-dimensional format are produced under computer control.

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BRIEF DESCRIPTION OF DRAWINGS

P A method for carrying out the invention is described in the
accompanying drawings in which:

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Figure 1 is a diagram illustrating the relationship of a 2-D source film image, left and right image pairs, and a composite 3-D image frame.

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Figure 2 is a schematic diagram of a system for carrying out an ~~implementation~~ ^{implementation} of the present invention.

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DETAILED DESCRIPTION

1P An immense amount of standard, 2-D motion ~~picture~~ ^{picture} material exists in the form of film and videotape. In addition, certain materials exist in the form of discrete 2-D image ~~sub-components~~ ^{sub-components}, such as
15 B animated cell and background paintings. As the use of 3-D
a exhibition and broadcast systems becomes more widespread, the
B conversion of existing 2-D programs to a format that will exhibit
B at least some 3-D or depth effects, when used with 3-D systems, is desired.

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B Extracting individual image elements or 3-D depth information
B from a 2-D film frame, or synthesizing 3-D information for those
elements, entirely by computer ~~equipped~~ ^{equipped} with artificial
a intelligence, is not now practical. Therefore, the embodiment of
25 the invention as described herein employs a high degree of human
interaction with the computer. However, as artificial
intelligence progresses, a predominantly or completely automated
system may become practical and is within the intended scope of
the invention.

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Figure 1 shows a frame 20 of a standard 2-D film or video motion
picture, consisting of a cross-hatched ~~background~~ ^{background} plane 21, a
large white circle 22 in the mid-ground, and a small black square
23 in the foreground. It is a 2-D representation of original 3-D
35 scene 10 comprising elements 11, 12 and 13, which is not

1 B available for direct 3-D photography. After human identification
of individual image elements and depth assignment, the computer
generates, from frame 10, a pair of coordinated left 30 and right
40 images with backgrounds 31 and 41, circles 32 and 42, and
5 squares 33 and 43 respectively. Note that the relative positions
of the square and circle are different in the left and right
images; this situation is similar to the parallax that might
result between left- and right-eye views if one were to have
viewed the original scene 10 directly. Three-dimensional format
10 frame 50 is generated by encoding the information in the left 30
and right 40 image pair, in a manner consistent with any one of a
B number of existing 3-D systems. The specific operation of these
B various 3-D systems is not the subject of the instant invention.

15 B Alternately, the steps of generating and encoding 3-D information
may be combined such that 3-D format frame 50 may be processed
directly from 2-D frame 20 B without generating left 30 and right
40 image pairs. In either case, 3-D format frame 50 when viewed
by human 60 through 3-D glasses 70 is perceived as 3-D scene 80,
20 containing elements 81, 82 and 83, which has at least some of the
3-D characteristics of original 3-D scene 10.
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Various systems for the encoding, display, projection, recording,
transmission or viewing of 3-D images exist, and new ~~systems~~ ^{systems} may
25 be developed. Specifically, various techniques for specifying,
encoding and viewing 3-D information may now, or come to, exist,
which do not make use of parallax offset and/or left and right
image pairs and/or viewing glasses, or which embody new
techniques or changes and ~~improvements~~ ^{improvements} to current systems.
30 Further, such systems may integrate information from more than
one 2-D source frame 20 into a single resultant 3-D frame 50. The
specifics of operation of such systems is not the subject of the
instant invention, however, preparation of 2-D program material
for such systems is.

1 P The offsets shown for elements 31, 32 and 33 in left frame 30 and
elements 41, 42 and 43 in right frame 40 are meant to be
illustrative and do not necessarily follow the correct rules for
image parallax. In fact, depending upon where viewer attention is
5 meant to be centered, different rules may apply. For example, one
technique is to give no parallax offset to far background
elements and to give progressively more parallax offset to
objects as they get closer. Alternately, attention may be
centered in the mid-ground with no parallax offset to mid-range
10 objects, some parallax offset to close-range objects and reverse
parallax offset to far-range objects. The particular placement of
objects and attention point in the 3-D scene is as much an art as
a science and is critical to the enjoyment of 3-D programs and,
in any event, is not meant to be the subject of this invention.

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Figure 2 shows a schematic of a system to implement the instant
invention. A 2-D film or video image 10 is input to a video
monitor 20 and to the scanning portion 41 of frame buffer 40.
Video monitor 20 is capable of displaying either the 2-D image
20 being input 10 or the output from display portion 42 of frame
buffer 40.

Frame buffer 40 consists of an image scanner 41 which can convert
the input image into digital form to be stored in a portion of
25 frame buffer memory section 44, a display section 42 which
creates a video image from the contents of a portion of memory
section 44, and a computer interface section 43 which allows the
computer CPU 50 to read from and write to the memory section 44.

30 Graphic input tablet 30 and stylus 35 allow the human operator to
input position information to the computer 50 which can indicate
the outline of individual image elements, choice of a specific
image element or part of an image element, depth specification,
choice of one of a number of functions offered on a 'menu', or
35 other information. An image cursor can be displayed on monitor 20

1 by frame buffer 40 to visually indicate the location or status of the input from the tablet 30 and pen 35. Text and numeric information can also be input by the operator on keyboard 55.

5 Computer CPU 50 is ^{equipped} ~~equipped~~ with software which allows it to interpret the commands and input from the human operator, and to process the digitized 2-D information input from ^B 2-D frame 10 into digital ^B 3-D frame information, based on said human commands and input. Said digital ^B 3-D frame information is then output by 10 output interface 60 (which may be similar to frame buffer 40 or of some other design) to a videotape recorder 70 or to a film recorder 75, capable of recording 3-D format frames. ^B

15 The system as described above operates as follows. A frame of the 2-D program is displayed on the video monitor for viewing by the ^B human operator. With the tablet and stylus the operator outlines various 2-D image areas to indicate to the computer the boundaries of various image elements to be ^{separately} ~~separately~~ processed. (For materials, such as animation ^{components} ~~components~~, that already exist as ^{separate} ~~separate~~ elements, the previous stage of the process may be 20 skipped.) Depth position information, in the third dimension, is determined for each image element, by a combination of operator input and computer analysis. Left and right image pairs or a ^B 3-D composite image is processed by the computer, from the ^B 2-D input image, based on the computer software and operator instructions. 25 Depending upon the particular 3-D system to be used, left- and right-image pairs may or may not be the final stage or an ^{intermediate} ~~intermediate~~ stage or bypassed entirely. Further, for some ^B 3-D systems, information from more than one 2-D source frame may be 30 combined into one ^B 3-D frame (or frame pair). In any event, the final ^B 3-D information is then collected on a videotape or film recorder. The process is then repeated for additional ^B 2-D frames. ^B

35 Each image element may be given a uniform depth designation which may cause the perception of 'cardboard cut-out' characters.

1 Alternately, different portions of a single image element may be
given different depth designations with the computer interpo-
lating depth coordinates over the entire element. For example, an
5 image element positioned diagonally in a frame may have its right
edge designated to be closer than its left edge. Alternately, one
feature of an image element, say a person's nose in a close-up,
might be designated as being closer than ³the rest of the image
element. In such manner, the computer would be instructed to
10 interpolate and process depth information over the entire image
element. Such processing of the image element, in accordance with
varying depth information, may result in the stretching, skewing
or other distortion of the image element.

Depth interpolation may also be carried out over time, between
15 frames. For example, an image element might be designated to be
close in one frame and to be far away in a later frame. The depth
of the image element may be interpolated for the frames between
the two designated frames. Further, the position of the image
element in the two dimensions of the film frame, and the shape of
20 the outline ~~separating~~ ^{separating} the image element from the rest of the
source image, may also be interpolated over time, between frames.
Linear and non-linear interpolation techniques are well known and
may be readily applied.

25 It is also possible to add random noise to the depth information
to eliminate the appearance of flat objects moving in space and
to help achieve greater realism.

For a particular image element, depth position may be derived by
30 the computer, alone or with operator input, by measuring the size
of the image element in a frame. For example, once a person were
outlined, his overall height in the 2-D film frame might be
extracted by the computer as an indication of depth distance.
Using knowledge, or making assumptions, about the object's ³real
35 size, and the characteristics of the camera and lens, the

- 1 distance of the object from the camera may be calculated by
applying well known principles of perspective and optics.
Alternately, if overall size cannot be easily extracted by the
5 computer, key points might be indicated by the operator for the
computer to measure. Comparing the change of size of an image
element in several frames will provide information about the
movement of the object in the third dimension.

a 10 It should be noted that horizontal parallax offsets are, by far,
more obvious, due to the fact that our eyes are *separated* in the
horizontal direction. However, vertical offset differences
between left- and right-eye views may also be appropriate.

a 15 As various image elements are *separated* and assigned depth
values, a situation develops where diverse objects exist in a
'three-dimensional space' within the computer. It should be noted
that, in order to display a realistic representation of the
entire scene, *forwardmost* ~~forwardmost~~ objects must obscure all or part of
a rearward objects with which they overlap (except in the case
20 where a *forwardmost* ~~forwardmost~~ object were transparent). When generating
left- and right-eye views, the pattern of overlap of image
elements, and thus the pattern of obscuring of image elements
will, in general, be different. Further, for image elements that
have been assigned non-uniform depth values (e.g., image elements
25 that are not flat or not in a plane perpendicular to the third
dimension) the intersection between these image elements, for the
purpose of one obscuring the other, may be non-trivial to
calculate. However, there are well known techniques, that have
been developed for computer image synthesis, that allow for the
30 sorting, intersection and display of diverse, overlapping 3-D
image elements. B

a As image elements are *separated* ~~separated~~ from background scenes or each
other, holes may develop. The computer software will compensate
35 for this by filling in missing information in one particular 2-D
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1 frame with the equivalent part of the image element from earlier or later frames whenever possible. Alternately, material to 'plug holes' may be created by the operator or by the computer from adjacent areas or may be newly synthesized. Further, as two image elements are separated from each other, the ^{forwardmost} ~~forwardmost~~ of the two may be moved closer to the viewer; hence, it may be appropriate to make it larger. Thus, the increased size may cover the gaps in the rearmost element of the two.

10 As part of the processing to be performed on the 2-D source image, individual image elements or composite images, ^B additional effects may be programmed into the computer to heighten the sense of depth. For example, shadows cast by one image element on another element or the background may be calculated and inserted; 15 far distant landscape elements may be made hazy or bluish to indicate remoteness; different image elements may be blurred or sharpened to simulate depth-of-field; or, the distance between close objects may be ^{exaggerated} ~~exaggerated~~ to emphasize their ^{separation} ~~separation~~.

^a There are, of course, other technical or artistic techniques that ^a 20 can be used to indicate depth in an image and which may also be incorporated into the image processing programs and would therefore be part of the invention as described herein. Therefore, the above examples are illustrative and should not be construed as limiting the scope of the invention. Alternately, 25 depth information may be intentionally distorted for effect or for artistic purposes.

^a ^{Improvements} ~~Improvements~~ may be made to the final product by including new image elements that were not part of the original 2-D source image. These could include 2-D image elements that ^B are then assigned depth values, ^B 3-D image elements created by ^B 3-D photography and then entered into the computer as left- and right-image pairs, for example, or synthetic 3-D computer generated graphics. In particular, since computer generated image ^B 35 elements can be created with depth information, they can be

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1 easily integrated into the overall 3-D scene with vivid effect.
For example, a 3-D laser blast could be created by computer image
synthesis such that it would in turn ^Bobscure and be obscured by
other image elements in an appropriate ^Bmanner and might even be
5 created so as to appear to continue beyond the front of the
screen into 'viewer space'.

Animated film ^{components} ~~components~~ usually have relatively few background
paintings, which are kept ^{separate} ~~separate~~ from the animated characters
10 ^Bin the foreground. For these, or for live 2-D filmed scenes, once
the foreground elements have been ^{separated} ~~separated~~ from the background,
^Bthe flat 2-D backgrounds may be replaced by 3-D backgrounds. The
^B3-D backgrounds might consist of computer generated graphics, in
which case depth information for the various elements of the
15 background would be available at the time of the background
^Bcreation. Alternately, 3-D backgrounds might be created using 3-D
photography, in which case depth information for the background
elements may be derived, by the computer, from the comparison of
^Bthe left- and right-image pairs of the 3-D background photographs
20 and applying known image processing and pattern recognition
^Btechniques. Alternately, depth information to create 3-D
backgrounds may be specified otherwise by operator input and/or
computer processing. Once depth information is available for the
various background elements, it may compared to depth information
25 for the other image elements with which it is to be combined in
^Beach frame. Thus, the 3-D background may itself have some depth
and, in effect, be a 'set' ₂ within which other image elements may
be positioned in front of, behind or intersecting various
background elements for added realism.

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It should be noted that, intended purpose and software algorithms
^Baside, the design and operation of the 3-D conversion system
described herein has many similarities with the black & white
footage colorization system described in applicant Geshwind's
35 ^Bpatent 4,606,625. They are both computer-aided systems which

1 display standard film images to an operator, allow the operator
to input information ~~separating~~ ^{separating} various image elements within the
frame, allow the operator to specify attributes (color in one
case, depth in the other) for the image elements, and cause the
5 computer to process new image frames from the original, based on
the operator input. Thus, the processing of 2-D black and white
footage to add both color and depth information would be much
more efficient than implementing each process ~~separately~~ ^{separately}.

10 The scope of the instant invention is the conversion or
processing of 2-D program material for use with any 3-D
exhibition or distribution system now in use or later developed,
but not the specific method of operation of any particular 3-D
system.

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It will thus be seen that the objects set forth above, among
those made apparent from the preceding description, are
efficiently attained and, certain changes may be made in carrying
out the above method and in the construction set forth.

20 Accordingly, it is intended that all matter contained in the
above description or shown in the accompanying figures shall be
interpreted as illustrative and not in a limiting sense.

CM Now that the invention has been described, what is claimed as new
25 and desired to be secured by Letters Patent is:

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